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ART. XXXV.—*On supposed Glaciation in Pennsylvania south of the Terminal Moraine;* by H. CARVILL LEWIS, Professor of Geology in Haverford College. With a map (Plate IV, but not numbered.)

IN a "Report on the Terminal Moraine in Pennsylvania and Western New York,[1] I have said (p. 45) that "with the exception of a narrow district which I have called the *fringe*, the line of drift hills which crosses Pennsylvania lies at the precise edge of the drift-covered district," and (p. 43) that this terminal moraine is a "line separating the glaciated from the non-glaciated regions."

But in his letter of transmittal, Professor J. P. Lesley, the State Geologist, in referring to the limit of glaciation, makes the following statement:[2]

"Two remarkable phenomena, however, stand in the way of a positive and final assertion respecting the limit of the southward extension of the northern ice, in spite of the well-marked line of its terminal moraine, viz: scratches observed on the mountains of Schuylkill and Dauphin County; and vast grooves or notches in the crest of the Kittatinny mountain, for which no explanation is suggested by the drainage system of the country.

(1.) "Respecting the first very little can be said, but that little is important.

"In 1850–51 Professor Edward Desor of Switzerland, and myself, observed glacial scratches pointing southward upon the bare outcrop of conglomerate which makes the crest of Locust mountain west of Ashland. The testimony of the distinguished glacialist to their genuineness is sufficient. We were both of us perfectly well acquainted with the nature and aspect of 'slickensides' and felt sure that these polished surfaces, grooves, etc., were not of that kind, nor could they have been produced in that way; for they crossed the eroded edges of the beds.

(2.) "Some years afterward I observed horizontal grooves traversing the natural vertical east wall of the small and unique notch in the crest of the Fourth mountain where it is crossed by the turnpike from Harrisburg to Halifax. The opposite west wall had been cut to the vertical by the engineers, and was covered with sections of blast holes; but the east wall had not been touched, and was covered with *horizontal* glacial grooves and scratches crossing the deeply south-dipping bed-planes. In this case I had no one with me to verify the observation, but I feel as sure of the nature of the exhibition as in the former case. . . .

(3.) "The Wind Gap is one of the strangest and most inexplicable features of the earth's surface. . . . I am not aware that any

[1] Report Z. Second Geological Survey of Pennsylvania, Harrisburg, 1884.
[2] P. xli.

serious attempt has been made to construct a satisfactory hypothesis of its origin. . . . A long, straight, sharp-crested ridge, 1000 feet high on a base two miles wide, is here, not split by a fault, nor gapped by a stream, but worn smoothly through to half its altitude. The raggedness of the mountain crest ceases and smoothly rounded slopes descend to the smoothly rounded bottom of the gap which is lined with sand and gravel. . . It is evidently a deep cross-groove smoothly made and finished by some agent of erosion acting slowly and continuously—but an agent quite different from a river. . . . I can see no serious objection to the supposition that the front of the ice-sheet may at one time have advanced the necessary two miles and banked itself against the mountain at the Wind Gap. . . . In any future investigation of the origin of the Wind Gap the fact that there extends southward from the level of the bottom of the Gap, a fan-shaped sloping plain of rounded bowlder drift which has evidently all come through the Wind Gap, and has probably been brought through it by the agent which made the gap (although that cannot be taken for granted) must be taken into consideration."

Professor Lesley then repeats an explanation for the origin of the Wind Gap which he made in 1882, that it was due to the overflow of a vast lake which he supposed to cover a large part of Monroe and Carbon Counties, which lake was due to a great ice-dam at the Lehigh Water Gap. But as this dam would have had to be 1100 feet high in order to deliver the water over the crest of the mountain when the Wind Gap was begun, and as the glacier did not cover the region about the Lehigh Gap, he grants that such a supposition is untenable.

(4.) He then mentions a topographical feature six miles west of the Lehigh Gap, saying:

"It looks as if the bowl had been made by some kind of waterfall; but if so the mass of water must have been extraordinarily great and must have shot clear of the top of the mountain—an arrangement only possible in case the back valley were filled with ice to a height exceeding that of the mountain."

In addition to the passages just quoted, there are a number of other statements made by different geologists which describe further supposed evidences of glaciation in Pennsylvania south of the terminal moraine.

(5.) Mr. C. E. Hall has published two short papers which are also quoted in the preface to Report Z. In the first of these[3] he calls attention to the bending over of slate outcrops both north and south of the Lehigh Gap, which he regards as due to the southeastward movement of a glacier.

(6.) Mr. Hall also mentions a mass of debris a few hundred yards north of the gap, concerning which he says:

[3] Proc. Amer. Philos. Soc., xiv, 620.

"The only explanation I can give of this, is, that it is a moraine formed by the glacier after it had receded through the gap, possibly a lateral moraine."

He also believes that the Wind Gap shows evidence of the passage of a glacier.

(7.) In his second paper[4] entitled "On Glacial Deposits in West Philadelphia," he describes a gravel opening between Spruce and Walnut streets west of 45th street in West Philadelphia, where, having found bowlders of Oneida conglomerate, Medina sandstone, Triassic shales, and probably Clinton and Oriskany, as also a few pieces of trap, he says:

"From all these evidences I have concluded that this belt of drift deposit is no other than a glacial moraine formed by the Schuylkill glacier receding from the site of the city."

He states also:

"that the surface of the gneiss where laid bare is comparatively smooth, and shows evidence of having been polished, though so soft as not to retain the marks of glaciation."

(8.) Prof. F. Prime, Jr., has stated[5] that

"A glacial moraine may be traced from the Wind Gap in the Kittatinny Mountain through Ackermanville, Bangor and Williamsburg to Portland on the Delaware river. . . . West of the Wind Gap no glacial moraine can be seen so far as the Lehigh river. That it existed, however, there is little doubt, and was probably washed away again by aqueous action, to be re-deposited as modified drift," etc.

(9.) Again he says in the same communication:

"Another glacial moraine also exists in the Saucon Valley south of the Lehigh; it extends from Friedensville almost to Bingen station on the North Pennsylvania railroad."

(10.) In his report on Lehigh County,[6] the same geologist states that, "distinct evidences were obtained of glacial deposits," and records his conviction that

"the glaciers, coming through the gaps of Kittatinny Mountain and in places riding over its crest, came down to the South Mountain." In the statement that in Lehigh County glacial scratchings "were, with a single exception, nowhere found; the subsequent erosion of the soft slates of the Hudson River group, and of the soluble underlying limestones, having removed all traces of any scratches which may have existed" he appears to add strong evidence of the truth of his conviction.

[4] Proc. Amer. Philos. Soc., xiv, 633.
[5] Proc. Amer. Philos. Soc., xviii, 85.
[6] Report DD, pp. 75–77, 1878.

(11.) Prof. J. F. Carll in his valuable report on the Oil Regions[7] includes an extended discussion of the glacial drift, and holds that

"besides the main southward movement of the glacier, every feature in the Allegheny valley south of Olean shows an ice movement *toward the north*," and "as there is no red rock in the northern branch valleys and no northern detritus in the southern branch valleys, . . . it follows that the northern ice-flow, southward, met a southern ice-flow, northward, and both moved westward side by side."[8] He makes the origin of this northward flowing glacier in the "upper branch valleys of the Allegheny River in Potter and M'Kean counties," and believes[9] that the Salamanca "Rock City" was formed by glacial erosion.

These eleven localities, each lying south of the terminal moraine, some of them considerably so, are, I believe, the only ones in Pennsylvania south of that line which have been regarded as showing evidences of glaciation by geologists of acknowledged ability. Several local writers in the State have mistaken weathered trap bowlders for glacial erratics, or fallen into similar obvious errors,[10] but these are not worthy of mention.

If these statements, given in such detail, remain unquestioned facts, it must be granted that the "terminal moraine," so-called, is a misnomer, and that the evidences usually relied on to distinguish glaciated from non-glaciated regions are insufficient.

It seems to be of importance therefore, that any investigations of the terminal moraine should be supplemented by careful inquiries into all reported evidences of glaciation south of that moraine.

It is proposed, therefore, to review each of the above eleven statements in turn.

The accompanying map represents by small colored circles the approximate position of each of the localities of supposed glaciation south of the moraine, numbered in accordance with the following descriptive paragraphs.

(1.) The striæ on the crest of Locust Mountain west of Ashland, and south of Mt. Carmel, have been frequently referred to,[11] and since they lie "25 miles south-southwest of the great moraine (Berwick)" are of the highest importance.

I have crossed Locust Mountain in three places west of Ashland, have walked along its summit south of Mt. Carmel for a considerable distance, and have explored, on foot and by

[7] Report III. [8] Loc. cit., p. 379. [9] p. 390.

[10] History of Chester County, Smith and Futhey, p. 186. History of Bucks County, Davis, p. 438, etc.

[11] MacFarlane's American Geological Railway Guide, p. 102. Report G6, xvii, Second Geological Survey of Penn., etc.

driving, the valleys both north and south of the mountain for many miles in each direction. I have also carefully examined the sides and ledges of the mountain and, thanks to careful instructions and a diagram given me by Professor Lesley, believe that I have succeeded in finding the very spot where Professors Lesley and Desor saw the striæ.

I found no moraines, no till, not a single transported or scratched bowlder, no kames or terraces, and no striæ. There was not a single sign of glaciation, and both mountains and valleys were in all respects similar to other non-glaciated mountain regions about the anthracite coal basins.

The mountain is formed mainly of Pottsville conglomerate (No. XII), a coarse white conglomerate with often large pebbles, and here characterized by numerous impressions of an unusually large calamite, probably *Calamites dubius* Artis (*Calamites bistriatus* Lesq.).

The impressions of this calamite are sometimes two to three feet long and from one to three inches in width, and are marked by a series of narrow parallel furrows, running longitudinally. The articulations are unusually distant and the parallel lines well marked. The impressions of this calamite are flat or only slightly rounded, often entirely colorless, no trace of the original fossil remaining, and, appearing often merely as a set of parallel lines crossing a face of conglomerate, have probably been mistaken for glacial striæ. The impressions of these calamites occur on the very ledge near the top of the mountain south of Mount Carmel which was supposed to be glaciated.

(2.) On the summit of Peters (Fourth) Mountain, where the Dauphin and Halifax turnpike crosses the sharp crest, is a small notch, some 15 feet deep, the east and west sides of which are nearly vertical walls of Pocono sandstone. The sandstone dips 65° S. 10° E., and there is a small coal vein in it part way down the mountain. After an examination of the region between here and Harrisburg, including the slopes and crest of the mountain, I was unable to find any trace of glacial action. The east wall of the notch is covered by numerous horizontal striæ, as stated by Professor Lesley, but these striæ are not of glacial origin, but are undoubtedly *slickensides.* The slickensides occur on the cleavage planes of the sandstone, these cleavage planes being at about right angles with the plane of bedding. Unlike a glaciated surface, the rock forms projecting angular crags, with irregular faces, cut by a series of cleavage planes, on several of which the slickensides appear. The slickensides do not make continuous lines nor occur on a single plane, thus differing from glacial striæ. Nor do they occur only on the surface, but run in *between* blocks of sand-

stone not yet separated. I hammered down some of these blocks and found the slickensides quite as well marked on the inner surface of the block just detached as they were on the vertical wall. This locality is over sixty miles south of the terminal moraine.

(3.) When studying the limits of glaciation in 1880 and 1881, I was aware of the statements that had been made concerning glacial action at the Wind Gap, and took special care to examine that locality thoroughly, particularly as it lies so near the terminal moraine. Within three miles of the gap, glaciation is proved by undoubted evidences. Scratched and transported bowlders, some of them of Adirondack granite, polished and striated rock surfaces, unmodified *till*, glacial lakes, kames and moraines, are all close at hand, but all stop suddenly at a point less than three miles away. I did not see a single scratched or transported bowlder in the gap, nor any striæ or other signs of glaciation. A long trench made for a projected railroad had been cut in the bottom of the gap, offering an excellent opportunity to study the character of the debris at that place. It presented no evidence of glacial action. The fragments were mostly angular, and composed of the same Medina sandstone (No. IV) which formed the two sides of the gap. They had evidently fallen there from the mountain. The "smoothly rounded slopes" referred to showed no evidence of glacial or aqueous erosion, their form being due to the mass of angular frost-broken talus which covers some of the crags.

North of the Gap, and at nearly the same level, the soil is filled with fragments of Clinton red shale and sandstone (No. V), being made of the underlying rock. No rounded or transported bowlders were here seen, although cliffs of Helderberg limestone and Oriskany sandstone occur immediately north. A few miles to the northeast, however, in the glaciated region, large blocks of both of these formations are strewn in abundance along the northern flank of the mountain.[12]

Nor could any "fan-shaped sloping plain of rounded bowlder drift" south of the gap be discovered. It is true that the whole valley south of the gap is strewn with water-worn rounded bowlders and with beds of clay, both of which were brought by waters issuing from the melting glacier a few miles eastward. I have been able to trace the course of a wide river, which, issuing from the base of the glacier west of Bangor, flowed westward past Pen-argil and Hellerville into the valley of Bushkill Creek, and thence to the Delaware. Another great stream flowed down the valley of Martin's creek, while at the same time there was a large sub-glacial drainage backward to Portland, as shown by the Portland kame.[13] The bowlders and

[12] V. Report Z, p. 88.

[13] Z, p. 69.

the bowlder-bearing clay which cover a great part of Northampton County south of the Wind Gap have clearly not come through the gap, but from the glacier on the south side of the mountain.

Immediately in front of the gap there is a great mass of sharp, frost-broken talus of Medina sandstone, which forms a sloping plain leading up to the gap. The rock fragments are not rounded or water-worn, but angular and often of large size. I am led to believe that all this work was accomplished long before the Glacial epoch.

An example on a small scale of the power of waters to carry sandstone blocks far away from their original outcrop, may be profitably studied within a few miles of Philadelphia, near King of Prussia, a locality which I briefly described some years ago.[14]

The Wind Gap does not seem to require any unusual or extraordinary origin. Like most mountain gaps, it appears to be the result of long continued pre-glacial erosion.

Its smooth outlines seem to me to be due to the uninterrupted course of atmospheric influences. Had a stream flowed through it in recent times, the talus would have been carried off and the sides of the gap become steep, as at the neighboring Delaware and Lehigh Gaps.

Still another consideration bears against the idea that the Wind Gap was cut down by a glacial stream.

A number of studies at points along the extreme edge of the glaciated area, where the moraine crosses river valleys, have led me to believe that neither the glacier at its cap nor the waters issuing from it have been able materially to modify the topography. In many cases the terminal moraine lies on the very floor at the bottom of a narrow valley. Had the glacial or post-glacial waters been able to excavate such a valley, the moraine would now lie *above* the stream. As instances, we have the moraine crossing the valleys of Fishing Creek, Columbia County; Great Valley Creek, Cattaraugus Co., N. Y.; the Susquehanna, Allegheny, Conewango, and Beaver Rivers. The evidence gathered from the conditions, on these and many other streams, is all opposed to any theory that the Wind Gap was made either by glacial waters or by ice.

(4.) The same arguments, that have been used in referring to the Wind Gap, are just as appropriate in considering the extraordinary hypothesis proposed to account for the Bake-oven. There is the strongest proof of the absence of all glacial action at this place. I find no evidence that the glacier approached the Bake-oven nearer than twenty miles.

(5.) The Lehigh River was one of the great waste-weirs of the melting glacier. All the way from Hickory Run, where

[14] Proc. Acad. Nat. Sc., 1880.

the moraine crosses it, down to its junction with the Delaware, heavy masses of water-borne drift mark the ancient flood, and show that it was 200 feet in depth. Where the banks of the river are steep, as they generally are as far down as the Lehigh Gap, the drift is represented by scattered bowlders only, all the rest having been washed away. Just north of the gap, for example, at a point one mile below Weissport, I found a large rounded bowlder of conglomerate six feet long lying upon a bank of shales of VIII, at an elevation of 150 feet above the river. Smaller ones occur up to a height of 180 feet. But south of the gap, where the easily eroded slates of III form an open rolling country, large masses of bowlders imbedded in a yellow brick clay cover the region on both sides of the river in beds sometimes more than ten feet deep. This deposit differs from glacial till in the rounded character of its bowlders, in the greater preponderance of clay, and in its more or less evident stratification. It certainly cannot be said to have "all the characteristics of a glacial deposit." It overlies Hudson River slate which, as Mr. Hall observed, is broken and crushed over, though not by a superincumbent glacier. The decomposed slates were naturally bent and crushed as the bowlder-laden flood crushed over them. Other cases could be cited at localities fifty miles farther south. A similar occurrence above the Lehigh Gap, also described by Mr. Hall, is of like character and origin.

(6.) The mass of debris across the mouth of the Aquanchicola Creek, supposed by Mr. Chance and Mr. Hall to be a moraine, has none of the characters of a moraine, either topographically or internally. Such accumulations are common at the meeting of two drift-laden streams. The materials are water-worn, and the bank is leveled off by water, presenting none of the contours of a true moraine. I could find no trace of glaciated surfaces anywhere in the vicinity. There is in fact nothing to indicate that this bank of drift is at all unusual or different from the other deposits along the Lehigh, which are the evident result of aqueous deposition.

On the so-called "Eddy-hill" just north of the Lehigh Gap I found no rounded stones or drift of any kind, and there is nothing to indicate that this conical hill made of Clinton red shale has been materially modified in shape since pre-glacial times.

(7.) In a former paper[15] I have endeavored to show that Mr. Hall was mistaken in supposing that there is a glacial moraine in West Philadelphia. The gravel deposit at that locality is identical with that which occurs all along the Delaware from Trenton to Wilmington, and belongs to what I have called the

[15] The Surface Geology of Philadelphia and vicinity. Proc. Acad. Nat. Sc., 1880.

"Philadelphia brick clay" and the "red gravel." It is a stratified deposit made at a time when this region was submerged to a depth of about 180 feet, and is bordered by the "Upland Terrace." It is, I believe, also a mistake to state that the underlying gneiss shows signs of polishing. As elsewhere about Philadelphia the gneiss is decomposed, and some of the decomposed portion has been mingled with the lower strata of the gravel. At many localities in the vicinity the gravel may be seen lying on very uneven surfaces of gneiss quite unlike the floors beneath true till.

(8.) Professor Prime has very naturally confounded the true moraine at Bangor and Aekermannville with the *Kame* which runs through Williamsburg (Mt. Bethel) and Bangor.[15] The topographical features of kames and moraines are very similar, and without a special examination of their internal structure are liable to be confounded.

(9.) The supposed moraine in the Saueon valley is merely a deposit of stratified drift, similar to those already described on the Lehigh and at Philadelphia. The bowlders are water-worn, not scratched, and lie at an elevation less than 180 feet above the river at Bethlehem.

(10.) Professor Prime's remarks about glaciation in Lehigh and Northampton Counties, south of the terminal moraine, prove to be due to the difficulty of distinguishing at times, between glacial *till* and aqueous deposits. It is true that as the glaciated area is approached from the south, the stratified surface deposits become very like true glacial drift. The bowlders become more numerous and larger, and stratification is not so evident. Occasionally also striæ are seen on the bowlders, especially in the larger river valleys, where the water was deep enough to float icebergs. Both Professor I. C. White and myself have experienced some difficulty of this kind in the valley of the Susquehanna, southwest of Berwick. But the absence of typical till, of striæ, and of moraines, and the fact that the deposits south of the terminal moraine are limited to districts below a fixed elevation, serve to distinguish them. I do not here include that, as yet, unexplained phenomenon which, more clearly shown in the western part of the State, I have called "*the fringe*."

As to the glacial striæ in Lehigh County, Professor Prime has admitted to me that his reference to them was due to a mistaken observation.

(11.) The only evidence upon which Professor Carll rests his conclusion as to the northward flow of a McKean County glacier, appears to be[16] the occurrence of pebbles and bowlders of the red rocks of the Mauch Chunk (XI), Pocono (X) and

[15] v. Report Z, p. 52, 53, 62. [16] Report III, p. 379.

Catskill (IX) formations in the valley of the Allegheny river at Olean and Allegany, the rocks mentioned occurring only to the south of these towns. But he seems to forget that the Allegheny river flows northward to these points, and that it is just as capable of carrying rock debris northward as the Delaware is of carrying it southward. There is no necessity for a glacier as a transporter.

I have made a careful examination of the high region which Professor Carll would make a glacial center, and have found in it no trace of glaciation. No smoothed rock surfaces, no striæ, no till, no perched erratics, and no striated pebbles were noticed in McKean County, which I believe to have completely escaped the glaciation that has invaded every other county of the northern tier in this State. The Salamanca "Rock City," which Mr. Carll thinks was cut down by a stream of ice, is a remnant of a nearly horizontal sheet of Pottsville conglomerate (XII). It lies just south of the moraine and probably within the "fringe." But that it is due either to the glacier or to the glacial floods is extremely improbable. "Rock cities" like "pulpit rocks" and "monument parks" are characteristic of a non-glaciated region, where long continued atmospheric erosion has been uninterrupted either by glaciers or floods. The well known function of a glacier is to obliterate angular prominences, not to create them. I have been able to find no glacial marks of any kind at the Salamanca Rock city, nor any evidence that its origin was different from that of the Olean Rock city or similar phenomena elsewhere in the non-glaciated district.

In conclusion, I may perhaps be permitted to say that, while regretting the necessity of making personal allusions to those for whom I have the highest regard, I have felt it to be necessary both in answer to certain requests that have been made,[17] and also as a vindication of my deduction as to the truly terminal character of the Pennsylvania moraine.

Germantown, Pa., July 28, 1884.

[17] *Science*, vol. ii, No. 41, p. 654.

NEW YORK

NEW JERSEY

SUPPOSED GLACIATED LOCALITIES IN PENNSYLVANIA SOUTH OF THE TERMINAL MORAINE.

NOTE.—The Glaciated area is shaded.